AN EXPERIMENT ON THE METHOD OF APPLICATION OF UREA ON RICE

By

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Foreword

For these years, urea is calling for its greater application in Taiwan as a new nitrogenous fertilizer which has not been well recognized by the farmers in this land. In fact, it is one of the oldest materials with which farmers knew to fertilize their land. Far before the chemical fertilizers being used, farmers used to dress their land with those organic manures such as animal excreta or night soil in which urea actually exist. However, urea today in our hands is a quite different material in appearance. It is a beautiful crystal or granule as white as snow. As for its chemical properties a brief explanation which will be necessary in application is presented in the following. Urea is characterized by 1) highest nitrogen percentage, 2) great solubility in water, but very small degree of dissociation, 3) completely neutral in reaction, 4) without acid radical 5) hygroscopic under high temperature. In comparing these properties with those of ammonium sulphate we will easily realize its superiority to the latter as well as its inferiority. It is well accepted that ammonium sulphate gives a deteriorating effect on the paddy soil through its long time application due to the acid radical. An interesting example is found in Japan and known as degraded paddy soil, the actual cause of which was reported partly due to the sulphate radical remaining in the soil. Urea, on the other hand, provides us with the nitrogen source which contains no acid radical, so it seems that urea is the most promising nitrogenous fertilizer in the future. Another property of urea to be kept in our mind is that the nitrogen in urea is readily converted to ammonia by the action of soil bacteria and the nitrogen will be absorbed by plants more in this form than in its original form.

According to the properties mentioned, attention must be called to the application of urea as well as to the storage. First, we may consider the ready loss with irrigation water due to the great solubility on one hand and very small degree of dissociation on the other. We know well that, when ammonium sulphate is dissolved in water it will dissociate to the cation of ammonium and anion of sulphate, then the cation will be strongly absorbed by soil colloid and thus prevents itself from being carried away by percolating water, but in urea the degree of dissocation is very small and it is hardly absorbed by soil colloid. Former experiment on the effectiveness of urea compared with other nitrogenous fertilizers in Taiwan indicated its being a little inferior to ammonium sulphate and the loss of urea with irrigation water was suggested to be responsible for the consequence. Therefore, in this experiment attention was given to the possible method which will prevent it from being

lost and consequently increase the effectiveness. To determine the best methed of application of urea, first we may consider the three essential factors which will be reponsible for the prevention of loss of urea, and accordingly determine the method, namely, 1) time of irrigation after application of urea, 2) placement of urea, 3) time of top dressing of urea. The first factor aims at the fact that the nitrogen in urea is readily converted to ammonia which will be strongly absorbed by soil colloid, then water must be irrigated after the convertion, lest the loss will not occur, but any further delay in irrigation will increase the nitrification of ammonia which is not preferable in paddy soil. The second and third factors are also considered to play important roles in the availability of fertilizer as claimed by many investigators.

The objective of this experiment is to determine the best method of application of urea, and the basic concept is hereto described. Readers will look into the details in the experimental part.

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Localities and Cooperating Agencies

Locality		
1.	Taipei	Taiwan Agricultural Research Institute (TARI)
2.	Taipei	Taipei District Agricultural Improvement Station (AIS)
3.	Taichung	Taichung District Agricultural Improvement Station
4.	Pingtung	Kaohsiung District Agricultural Improvement Station
5.	Hsinchu	Hsinchu District Agricultural Improvement Station
6.	Chiayi	Chiayi Branch Station (TARI)
7.	Lotung	National Bureau of Agricultural Research

Experimental Design

Experimental factors:

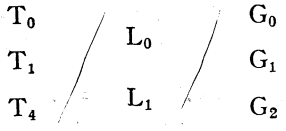
a. Time of irrigation after application of urea
   - G_0 Immediately after application
   - G_1 3 days after application
   - G_2 6 days after application

b. Placement of urea
   - L_0 Surface placement
   - L_1 Deep placement

c. Time of top dressing of urea
   - T_0 All applied as basal dressing
   - T_1 ½ applied as basal dressing, ½ applied as top dressing 20 days after transplantation.
   - T_2 1/3 applied as basal dressing, 1/3 applied as lst top dressing 20 days after

transplantation, 1/3 as 2nd top dressing 40 days after transplantation.

Note: Double split plot design is adopted with 4 or 3 replications.



Field arrangement

	L_0			L_1		
G_0	T_0	T_1	T_2	T_0	T_1	T_2
G_1	T_0	T_1	T_2	T_0	T_1	T_2
G_2	T_0	T_1	T_2	T_0	T_1	T_2

Plot size is 1/1000 ha. The rate of $N:P_2O_5:K_3O$ is 80:80:80 kg/ha. Yields of rough rice and straw in two crops are given in table 1 to 4.

Laboratory Tests

Some laboratory tests which seem to be necessary in reference to the field experiment are carried out.

1. General Analysis of Soils in the Experimental Localities.

Soil sample	pH	Mechanical analysis				Organic matter	Total N	Available P	Available K	Absorption capacity of NH_4^+ mgN≡ per 100g soil
		Sand %	Silt %	Clay %	Texture %	%	%	kg/ha	kg/ha	
Lotung	5.20	36.2	46.8	17.0	L	3.51	0.188	20	150	166
Taipei (TARI)	4.70	19.0	58.0	23.0	SiL	1.55	0.133	5	90	169
Taipei (AIS)	4.65	34.8	45.8	19.4	L	1.63	0.127	25	100	159
Hsinchu	5.92	22.0	49.0	29.0	CL	2.47	0.157	7	80	263
Taichung	4.90	48.2	35.8	16.0	SiL	1.29	0.087	7	80	166
Chiayi	6.10	27.2	56.8	16.0	SiL	1.21	0.074	12	120	152
Pingtung	6.11	18.0	53.6	28.4	SiCL	2.60	0.218	10	120	131
Pingchen*	4.99	27.2	30.8	42.0	C	2.28	0.077	2	140	228

Note: pH by quinhydrone electrode. Mechanical analysis by hydrometer method. Organic matter by rapid titration method. Total nitrogen by Kjeldal's method. Available P & K by Peech's method. Absorptive capacity of NH_4^+ according. to the "Methods of Soil Analysis" by Funabiki.

*This is not included in the field experiment.

2. Determination of the Rate of Decomposition of Urea.

Method of determination:

100g of air-dry soil is placed in a beaker and flooded with 100cc. of water which contains 0.1g of urea. The beaker is placed under the room temperature ranging from 25°C to 29°C and subjected to analysis in due time. Seven beakers provide for one determination. Soil and urea mixture is filtered and washed with 500cc. of water, the urea contained in the filtrate is determined by urease method.

The Rate of Decomposition of Urea in the Soils of Experimental Localities.

(Figures express the percentage of urea undecomposed of the original amount)

Time in days \ Soil sample	Lotung	Taipei (TARI)	Taipei (AIS)	Hsinchu	Taichung	Chiayi	Pingtung	Pingchen
0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1	70.63	91.51	93.91	32.15	94.00	82.13	70.01	89.64
2	8.97	57.15	76.60	14.29	63.21	19.65	9.02	67.86
3	5.59	16.07	55.32	6.58	55.70	12.50	2.17	60.71
4	—	6.51	18.34	—	32.55	4.20	—	5.81
5	—	2.32	4.56	—	4.02	—	—	—
6	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—

3. Determination of Ammonia Evaporated by the Application of Urea.

Method of determination:

200g of air dry soil is placed in 500cc. Erlenmeyer flask flooded with 200cc. of water which contains proper amount of urea or ammonium sulphate equivalent to 100 or 200 mg of nitrogen as indicated in the following table. The flask is fitted with rubber stopper and connected to the standard acid solution. An air current nearly 40cc. of air per second is induced to the flask for 10 minutes twice a day to replace all the air originally exist in it, and the expelled air is in turn induced to the standard acid solution. A blank test is conducted simultaneously, and after one week the remaining acid is titrated by standard alkaline solution. The volume of standard alkaline solution consume in the back titration is subtracted from that in blank test. Number of cc. of difference is converted to the amount of nitrogen by multiplying the factor.

The Amount of Ammonia Evaporated by the Application of Urea or Ammonium Sulphate within one Week from the Soils of Experimental Localities.

Soil sample	Amount of N in urea form (mg)	Amount of N evaprtd in NH_3 form (mg)	Percentage of loss	Amount of N in $(NH_4)_2SO_4$ form (mg)	Amount of N evaprtd in NH_3 form (mg)	Percentage of loss
Taipei (TARI)	100	0.7	0.7	200	0.0	0.0
	200	5.2	2.6			
Lotung	100	3.7	3.7	200	0.0	0.0
	200	7.4	3.7			
Taipei (AIS)	100	0.6	0.6	200	0.0	0.0
	200	3.4	1.7			
Hsinchu	100	1.0	1.0	200	0.0	0.0
	200	2.3	1.2			
Taichung	100	0.0	0.0	200	0.0	0.0
	200	1.4	0.7			
Chiayi	100	3.2	3.2	200	0.2	0.1
	200	6.2	3.1			
Pingtung	100	3.6	3.6	200	0.4	0.2
	200	7.0	3.5			

Statistical Analysis

Analysis of variance is conducted according to the following degrees of freedom.

Source of variation	Degrees of freedom (4 replication)	Degrees of freedom (3 replication)
Block	3	2
G	2	2
Error (a)	6	4
L	1	1
L x G	2	2
Error (b)	9	6
T	2	2
T x L	2	2
T x G	4	4
T x G x L	4	4
Error (c)	36	24
Total	71	53

Note: G represents the time of irrigation; L the placement of urea and T the time of top dressing.

The comparisons among the main effects are given in table 5 to 8.

In conducting the analysis the author had a certain feeling which is well descrided by Snedecor in his "Statistical Methods" as follows: "Elaborate statistics are no substitute for meticulous experimentation" and "It is only by a combination of appropriate design, skillful conduct of the experiment and suitable statistical method that the investigator is assured of reliable evidence upon which to base his decision." Far greater mean square of error compared with that of treatment effect and smaller mean square of error (a) compared with that of error (c), which occurred occasionally in some experimental localities suggest an ill-management in the field resulting in heteroginous distribution of error, and render the results of analysis meaningless. Reader is referred to the "On the Assumptions of Variance Component Analysis and Test of Significance" by Wang Chueh-Ming.

Discussion

With these three factors subjected to the experiment, one wonld expect the most complicated action of the time of irrigation, the effect of which is associated with the rate of ammonification of urea which in turn is governed by many factors such as temperature, soil texture, pH, moisture content, organic matter and activity of microorganism. Therefore, the experiment must be so designed as to furnish the most precise measurement on the result effected by it, in which we have failed. It is well known that one with split plot design may expect a more sensitive detection in the differences among the subtreatments than among the maintreatments, owing to

the greater degrees of freedom of error and less soil heterogeneity in the former. Then the time of irrigation must be arranged in subtreatments accordingly, but in this case it is almost impossible to conduct such an experiment in which irrigation is to be controlled in every subplot which is arranged randomly in the field, even with its being arranged in mainplot every caution must de paied in the handling in order to avoid any error conterminating the result. Moreover, it is quite unfortunate to have encountered heavy rainfall or drought during the treatment which is beyond our control and consequently spoil the experiment. In fact, a serious drought occurred in most of the localities in the south of Taiwan in the first crop and occasional shower in the second as a whole.

From another point of view, though so many factors may be indicated to have their ultimate account for the effect of the time of irrigation, the actual cause to bring it in action is the percolating water. In other words, the effect of the time of irrigation will be more apparent in the soil where the leaching takes place intensively. In this respect, the soils in the experimental localities in which the texture ranges from silt loan to clay loan seem to be more difficult to bring out a notable result than lighter soil, so far as the time of irrigation is concerned.

Referring to the data, one will readily notice the discrepancies in the results of the time of irrigation among the experimental localities, and though some were found significant may conflict with our inference in such a manner as to render the results quite suspicious. The laboratory test on the decomposition of urea indicates that most of the urea added in the soil will decompose within 3 to 5 days, and accordingly the most profitable time of irrigation will be 3 to 5 days after the application.

The results of the placement of urea, on the other hand, show a good concordance among the experimental localities and high significance with few exception. The effect may be attributed to the more ideal ammonification of urea and greater reserve by soil colloid. A noticeable fact was obtained in the test on evaporation of amonia in which greater extents of evaporation of ammonia is found by the application of urea. Though the figures in the table can not be applied to indicate the actual amount of evaporation of ammonia in the field, they would reveal the trend that predominates in the field. The amount of ammonia evaporated may be still higher under the field conditions owing to the greater free space and air current accompanied by intense sunlight. Under this condition it seems quite probable that evaporation will be more vigorous in the place of surface placement than of deep placement.

Now, the time of top dressing is to be discuseed here. We can imagine a smaller proportion of loss of fertilizer by occasional application in smaller portions than will it occur when the fertilizer is applied at one time in a larger portion. However, the effect of the time of top dressing is more significant in the plant physiology than in the prevention of loss. During the growth of rice the plant will display a series of different extent of demand for a certain element of nutrition. Top dressing aims at this fact to provide the plant with the proper nutrition supply according to its

demand. In this experiment only the early period is concerned, and it is desirable to extend the period to the time of earing, but this requires another specialized experiment to accomplish it, and obviously can not be included in this experiment. A highly significant effect is obtained by top dressing as shown in the table.

A brief examination should be made on the laboratory test, though some were referred to in connection with field experiment in the above, it is desirable to bring out any significant correlation between the rate of decomposition of urea and soil properties. For this purpose more soil samples which variate greatly in property should be necessary. In this occasion, only limited samples may lead one to fallacy. However, organic matter and neutral reaction seem to accelerate the rate of decomposition as shown by the data, that greater rate of decomposition is found mostly in the soils which is high in organic matter and more neutral in reaction. This fact suggests that a more favourable condition for the soil bacteria is preferable to increase the rate of decomposition. As for the evaporation of ammonia by the application of urea, the mechanism involved in the process is not well known, however, the alkaline reaction and instability of ammonium carbonate which is the reasonable product of the decomposition of urea seem to be responsible for the evaporation. Greater amount of evaporation of ammonia seems to be associated with greater rate of decomposition of urea with one exception in Hsinchu soil in which a rather high absorptive capacity of ammonia is found.

In these laboratory tests, one aspect to be under consideration is that the amount of nitrogen added to soil is in a proportion equivalent nearly 1000 or 2000 kg of nitrogen per hectare. (2×10^6 kg of soil per hectare is assumed). It is much greater than in the field. A great dissimilarity in condition between field and laboratory together with this fact makes the results obtained in these tests doubtful and serve merely as an approximation in the field.

Recommendation

Recommendation for the method of application of urea based on this experiment should be made, however, more elaborate experiments are needed to serve for a more detailed recommendation and here only an outline is given. When urea is to be used as base manure in paddy soil, complete mixting with surface soil is advisable. In the soils of light texture, field should be drained before application and flooding after 3 or 4 days seems to be most profitable. Application with compost or liming in acid soil is also recommended. Urea applied once or twice as top dressing at appropriate time seems to increase the yield significantly. In this occasion mixing with soil is also aimed, and top dressing prior to weeding may provide for the purpose.

Summary

1. An experiment on the method of application of urea, in which time of irrigation,

placement of urea, and time of top dressing are concerned, was conducted during 1955 for two crops in seven localities.

2. Some laboratory tests consisting of general anlalysis of the soils, determination of the rate of decomposition of urea and of amount of ammonia evaporated by application of urea are also carried out.
3. Deep placement and top dressing are found significantly effective to increase the yield of rice, however, the effect of the time of irrigation is still in question and more elaborate experiments should be needed to bring it to light.
4. Most of the urea applied in the soils of the experimental localities will decompose within 3 to 5 days, and evaporation of ammonia by the application of urea is very significant as compared with ammonium sulphate.
5. Recommendation for the method of application of urea is also made based upon this experiment.

Table 1 : Yields of Paddy and Their Indices in the 1st Crop. (Unit:kg/ha)

Locality / Treatment	Taipei TARI	Lotung	Taipei AIS	Hsinchu	Taichung	Chiayi	Pingtung
$G_0L_0T_0$	1805	3510	2760	2805	5570	3440	4130
	70.9	95.9	102.5	94.0	101.8	98.5	99.6
T_1	2010	3452	2853	3168	5430	3437	3677
	79.0	94.3	105.9	106.1	99.2	98.4	88.7
T_2	2155	3432	2643	3238	5700	4027	4307
	84.7	93.7	98.1	108.5	104.1	115.3	103.9
$G_0L_1T_0$	2065	3632	2750	2965	5573	3343	4213
	81.1	99.2	102.1	99.3	101.8	95.7	101.6
T_1	2340	3525	2367	3005	5547	3533	4110
	91.9	96.3	87.9	100.7	101.3	101.1	99.1
T_2	2540	3338	2787	3435	5200	3817	4220
	99.8	91.2	103.5	115.1	95.0	109.3	101.8
$G_1L_0T_0$	2070	3128	2520	2580	5587	3263	4205
	81.3	85.4	93.6	86.4	102.1	93.4	101.4
T_1	2205	3272	2620	2822	5503	3250	3830
	86.6	89.4	97.3	94.5	100.5	93.0	92.4
T_2	2345	3302	2570	2972	5397	3500	3853
	92.1	90.2	95.4	99.6	98.6	100.2	92.9
$G_1L_1T_0$	2510	3852	2433	3088	5643	3387	4473
	98.6	105.2	90.3	103.4	103.1	97.0	107.9
T_1	2545	3662	2693	2985	5473	3493	4146
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
T_2	2595	3442	2337	3329	5503	3953	4437
	102.0	94.0	86.8	111.5	100.5	113.0	107.0
$G_2L_0T_0$	2300	3098	1920	2625	5647	3320	3463
	90.4	84.6	71.3	87.9	103.2	95.1	83.5
T_1	2460	3225	2077	2890	5403	3487	3653
	96.7	88.1	77.1	96.8	9.87	99.8	88.1
T_2	2380	3068	1980	3212	5500	3743	4087
	93.5	83.8	73.5	107.6	100.5	107.2	98.6
$G_2L_1T_0$	2545	3502	2133	2738	5787	3170	3827
	100.0	95.6	79.2	91.7	105.7	90.8	92.3
T_1	2380	3420	1950	2948	5593	3227	3753
	93.5	93.4	72.4	98.8	104.0	92.4	90.5
T_2	2305	3232	2290	3315	5603	3383	3853
	90.6	88.3	85.0	111.1	102.4	96.9	92.9

Table 2 : Yields of Straw and Their Indices in the 1st Crop. (Unit:kg/ha)

Treatment \ Locality	Taipei TARI	Lotung	Taipei AIS	Hsinchu	Taichung	Chiayi	Pingtung
$G_0L_0T_0$	2015 67.5	3785 77.9	3440 102.6	no data available	6437 109.7	5467 122.4	3533 104.9
T_1	2260 75.7	4068 83.7	3427 102.2		5267 89.7	5533 123.9	2983 88.6
T_2	2405 80.6	4712 97.0	3407 101.6		5967 101.7	5600 125.4	3717 110.4
$G_0L_1T_0$	2340 78.4	4730 97.3	3410 101.7		5833 99.4	4867 109.0	3583 106.4
T_1	2580 86.4	4832 99.4	3303 98.5		5700 97.1	4867 109.0	3317 98.5
T_2	2540 85.1	4885 100.5	3303 98.5		5867 100.0	5333 119.4	3633 107.9
$G_1L_0T_0$	2280 76.4	3625 74.6	3443 102.7		6333 107.9	4467 100.0	3333 99.0
T_1	2550 85.4	3842 79.1	3303 98.5		5767 98.3	4800 107.5	3167 94.1
T_2	2670 89.4	4562 93.9	3257 97.1		5767 98.3	4667 104.5	3367 100.0
$G_2L_1T_0$	2995 100.3	4865 100.1	3167 94.4		6333 107.9	4800 107.5	3783 112.4
T_1	2985 100.0	4860 100.0	3353 100.0		5867 100.0	4467 100.0	3367 100.0
T_2	3100 103.8	5310 109.3	3000 89.5		6233 106.2	5867 131.4	4033 120.0
$G_2L_0T_0$	2840 95.1	3378 69.5	2890 86.2		6167 105.1	5200 116.4	2850 84.6
T_1	2745 92.0	3642 75.0	3107 92.7		6133 104.5	4533 101.5	3017 89.6
T_2	2795 93.6	4055 83.5	2810 83.8		5933 101.1	4733 106.0	3483 103.4
$G_2L_1T_0$	2915 97.7	4608 94.8	3250 96.9		6333 107.9	5333 119.4	3283 97.5
T_1	2640 88.4	4130 85.0	2997 89.4		5933 101.1	5533 123.9	3333 99.0
T_2	2625 87.9	4502 92.7	2887 86.1		6133 104.5	5600 125.4	3333 99.0

Table 3 : Yields of Paddy and Their Indices in the 2nd Crop. (Unit:kg/ha)

Treatment \ Locality	Taipei TARI	Lotung	Taipei AIS	Hsinchu	Taichung	Chiayi	Pingtung
$G_0L_0T_0$	2350	2582	2390	2080	2893	2947	3480
	106.3	88.3	95.1	120.1	87.9	101.9	109.6
T_1	2355	2390	2263	1958	3477	3540	3383
	106.6	81.7	90.0	113.1	105.6	122.4	106.5
T_2	2215	3015	2373	2058	3733	3543	3493
	100.2	103.1	94.4	118.8	113.4	122.5	110.0
$G_0L_1T_0$	2315	2365	2230	1962	3633	3063	3323
	104.8	80.9	88.7	113.3	110.3	105.9	104.6
T_1	2255	2388	2390	2160	3757	3200	3260
	102.0	81.6	95.1	124.7	114.1	110.6	102.6
T_2	2260	3002	2397	2078	4070	3403	3203
	102.3	102.6	95.4	120.0	123.6	117.6	100.8
$G_1L_0T_0$	2220	2750	2410	1945	2960	3323	3577
	100.5	94.0	95.9	112.3	89.9	114.9	112.6
T_1	2335	2662	2457	1775	2877	2897	3300
	105.7	91.0	97.8	102.5	87.4	100.1	103.9
T_2	2230	2894	2353	1775	3937	3167	3467
	100.9	98.9	93.6	102.5	119.6	109.5	109.1
$G_1L_1T_0$	2115	3250	2337	1805	2967	2960	3460
	95.7	111.5	93.0	104.2	90.1	102.3	108.9
T_1	2210	2925	2513	1732	3293	2893	3177
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
T_2	2245	3418	2630	1922	3833	3340	3403
	101.6	116.9	104.6	111.0	116.4	115.5	107.1
$G_2L_0T_0$	2195	2545	2397	1875	3147	3033	3053
	99.3	87.0	95.4	108.3	95.6	104.9	96.1
T_1	2520	2645	2510	1888	3197	2863	3120
	114.0	90.4	99.9	109.0	97.1	99.0	98.2
T_2	2445	3038	2473	2262	3600	2933	3143
	110.6	103.9	98.4	130.6	109.3	101.4	98.9
$G_2L_1T_0$	2315	3212	2463	2162	3417	3280	3380
	104.8	109.8	98.0	124.8	103.8	113.4	106.4
T_1	2115	2980	2427	1922	3643	3100	3127
	95.7	101.9	96.6	111.0	110.6	107.2	98.4
T_2	2015	3372	2343	1948	4227	3727	3140
	91.2	115.3	93.2	112.5	128.4	128.8	98.8

Table 4 : Yields of Straw and Their Indices in the 2nd Crop. (Unit:kg/ha)

Locality / Treatment	Taipei TARI	Lotung	Taipei AIS	Hsinchu	Taichung	Chiayi	Pingtung
$G_0L_0T_0$	4490	3460	2687	3795	3543	3947	3433
	108.2	87.5	83.4	105.4	90.3	101.6	112.6
T_1	4650	3552	2533	4112	3547	4233	3200
	112.1	89.8	78.6	114.2	90.4	108.9	104.9
T_2	4390	3942	2917	4225	3990	3887	3283
	105.8	99.7	90.5	117.4	101.7	100.0	107.6
$G_0L_1T_0$	4620	3845	2487	4250	3997	3990	3067
	111.3	97.2	77.2	118.1	101.9	102.7	100.6
T_1	4520	3775	2937	4162	4013	3667	3100
	108.9	95.4	91.1	115.6	102.3	94.4	101.6
T_2	4690	3780	3093	4205	4667	4215	3267
	113.0	95.6	96.0	116.8	119.0	108.4	107.1
$G_1L_0T_0$	4310	3620	3003	3525	3450	4177	3233
	103.9	91.5	93.2	97.9	87.9	107.5	106.0
T_1	4810	3922	3223	3688	3713	4460	3183
	115.9	99.1	100.0	102.5	94.6	114.8	104.4
T_2	4050	3555	2950	3838	4163	4077	3267
	97.6	89.9	91.5	106.6	106.1	104.9	107.1
$G_1L_1T_0$	3970	4180	3147	3600	3277	4237	3067
	95.7	105.7	97.7	100.0	83.5	109.0	100.6
T_1	4150	3955	3223	3600	3923	3887	3050
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
T_2	4380	3892	3447	4000	4140	4180	3017
	105.6	98.4	107.0	111.1	105.5	107.6	98.9
$G_2L_0T_0$	4260	3645	2697	3488	3473	3640	2783
	102.7	92.1	83.7	96.9	88.5	93.7	91.3
T_1	4510	3808	3020	3988	3627	3757	3250
	108.7	96.3	93.7	110.8	92.5	96.7	106.6
T_2	4165	3738	3113	4225	4230	3780	3217
	100.4	94.5	96.6	117.4	107.8	97.3	105.5
$G_2L_1T_0$	4320	4720	2587	4350	3907	3920	3233
	104.1	119.3	80.3	120.8	99.6	100.9	106.0
T_1	4400	4195	2997	4050	4010	4103	3283
	166.0	106.0	93.0	112.5	102.2	105.6	107.6
T_2	4180	4232	3070	4262	4377	4447	3050
	100.7	107.0	95.3	118.4	111.6	114.4	100.0

Table 5 : Comparisons among the Main Effects on the Yields of Paddy in the 1st Crop. (Unit:kg/ha)

Lotung				Taipei (AIS)				Taipei (TARI)				Taichung			
	Mean				Mean				Mean				Mean		
G_0	3482			G_0	2693			G_2	2395			G_2	5606		
G_1	3443	39		G_1	2529	164		G_1	2378	17		G_1	5518	88	
G_2	3258	224	183	G_2	2058	635**	471*	G_0	2153	242*	225	G_0	5503	103	15
	F nonsignificant				L. S. D. 305 ; 505				L. S. D. 227 ; 343				F nonsignificant		
L_1	3512			L_0	2438			L_1	2425			L_1	5558		
L_0	3276	236**		L_1	2416	22		L_0	2192	233**		L_0	5526	32	
	L. S. D. 94 ; 136				F nonsignificant				L. S. D. 102 ; 146				F nonsignificant		
T_0	3454			T_2	2434			T_2	2387			T_0	5634		
T_1	3426	28		T_1	2427	7		T_1	2323	64		T_1	5508	126	
T_2	3303	151*	123*	T_0	2419	15	8	T_0	2216	171**	107*	T_2	5484	150	24
	L. S. D. 115 ; 155				F nonsignificant				L. S. D. 86 ; 115				F nonsignificant		

Hsinchu				Pingtung				Chiayi			
	Mean				Mean				Mean		
G_0	3103			G_1	4157			G_0	3599		
G_1	2963	40		G_0	4109	48		G_1	3474	125	
G_2	2955	48	8	G_2	3773	384	336	G_2	3388	211	86
	F nonsignificant				F nonsignificant				F nonsignificant		
L_1	3089			L_1	4115			L_0	3496		
L_0	2924	65		L_0	3911	204		L_1	3479	17	
	F nonsignificant				F nonsignificant				F nonsignificant		
T_2	3250			T_2	4126			T_2	3737		
T_1	2970	280**		T_0	4052	74		T_1	3404	333**	
T_0	2800	450**	170*	T_1	3862	264**	190	T_0	3321	416**	83
	L. S. D. 138 ; 185				L. S. D. 193 ; 262				L. S. D. 169 ; 229		

Table 6 : Comparisons among the Main Effects on the Yields of Straw in the 1st Crop. (Unit:kg/ha)

Lotung			Taipei (AIS)			Taipei (TARI)			Taichung		
	Mean			Mean			Mean			Mean	
G_1	4511		G_0	3382		G_1	2764		G_2	6106	
G_0	4502	9	G_1	3254	128	G_2	2760	4	G_1	6050	62
G_2	4053	453** 449**	G_2	2990	392** 264**	G_0	2356	408* 404*	G_0	5845	267 205
	L. S. D.	164 ; 248		L. S. D.	215 ; 358		L. S. D.	367 ; 555		F nonsignificant	
L_1	4747		L_0	3231		L_1	2747		L_1	6026	
L_0	3963	784**	L_1	3186	45	L_0	2507	240**	L_0	5974	52
	L. S. D.	190 ; 273		F nonsignificant			L. S. D.	160 ; 230		F nonsignificant	
T_2	4671		T_0	3267		T_2	2689		T_0	6238	
T_1	4229	442*	T_1	3248	19	T_1	2627	62	T_2	5983	256*
T_0	4165	506** 64	T_2	3110	157* 138*	T_0	2564	125 65	T_1	5778	461** 205
	L. S. D.	138 ; 185		L. S. D.	122 ; 165		F nonsignificant			L. S. D.	261 ; 354

Pingtung			Chiayi		
	Mean			Mean	
G_1	3508		G_0	5278	
G_0	3461	47	G_2	5155	123
G_2	3217	291 244	G_1	4844	434 311
	F nonsignificant			F nonsignificant	
L_1	3519		L_1	5185	
L_0	3272	247**	L^0	5000	185
	L. S. D.	210 ; 318		F nonsignificant	
T_2	3594		T_2	5300	
T_0	3394	200**	T_0	5022	278
T_1	3197	397** 197*	T_1	4956	344 66
	L. S D.	168 ; 227		F nonsignificant	

Table 7 : Comparisons among the Main Effects on the Yields of Paddy in the 2nd Crop. (Unit:kg/ha)

Lotung				Taipei (AIS)				Taipei (TARI)				Taichung			
	Mean				Mean				Mean				Mean		
G_1	2985			G_1	2450			G_0	2292			G_0	3594		
G_2	2965	20		G_2	2436	14		G_2	2268	24		G_2	3538	56	
G_0	2624	361*	341*	G_0	2341	109	95	G_1	2226	66	42	G_1	3311	283*	227*
	L. S. D. 316 ; 476				F nonsignificant				F nonsignificant				L. S. D. 195 ; 324		
L_1	2991			L_1	2414			L_0	2318			L_1	3649		
L_0	2724	267**		L_0	2403	11		L_1	2205	113*		L_0	3314	335*	
	L. S. D. 133 ; 191				F nonsignificant				L. S. D. 95 ; 137				L. S. D. 224 ; 340		
T_2	3123			T_2	2428			T_1	2298			T_2	3900		
T_0	2786	337**		T_1	2427	1		T_0	2252	46		T_1	3374	526**	
T_1	2665	458**	121	T_0	2371	57	56	T_2	2235	63	17	T_0	3170	730**	204*
	L. S. D. 133 ; 179				F nonsignificant				F nonsignificant				L. S. D. 182 ; 247		

Hsinchu				Pingtung				Chiayi			
	Mean				Mean				Mean		
G_0	2049			G_1	3397			G_0	3283		
G_2	2010	39		G_0	3357	40		G_2	3156	127	
G_1	1826	223**	184**	G_2	3161	236**	196*	G_1	3097	186	59
	L. S. D. 195 ; 144				L. S. D. 138 ; 223				F nonsignificant		
L_1	1966			L_0	3355			L_1	3219		
L_0	1949	17		L_1	3275	60		L_0	3139	80	
	F nonsignificant				F nonsignificant				F nonsignificant		
T_2	2007			T_0	3379			T_2	3352		
T_0	1972	35		T_2	3308	71		T_0	3101	251	
T_1	1906	101	66	T_1	3228	151**	80	T_1	3082	270	21
	F nonsignificant				L. S. D. 97 ; 132				F nonsignificant		

Table 8 : Comparisons among the Main Effects on the Yields of Straw in the 2nd Crop. (Unit:kg/ha)

Lotung	Taipei (AIS)	Taipei (TARI)	Taichung
Mean	Mean 5	Mean	Mean
G_2 4056	G_1 3166	G_0 5472	G_0 3959
G_1 3854 202	G_2 2914 252*	G_2 5161 311**	G_2 3937 22
G_0 3726 330* 128	G_0 2776 390** 133	G_1 5134 338** 27	G_1 3778 181 159
L. S. D. 266 ; 403	L. S. D. 214 ; 371	L. S. D. 191 ; 290	F nonsignificant
L_1 4064	L_1 2999	L_0 4404	L_1 4034
L_0 3694 370**	L_0 2905 94	L_1 4358 46	L_0 3749 285**
L. S. D. 130 ; 187	F nonsignificant	F nonsignificant	L. S. D. 169 ; 256
T_0 3912	T_2 3098	T_1 4507	T_2 4261
T_1 3868 44	T_1 2989 109	T_0 4328 179*	T_1 3806 455**
T_2 3357 55 11	T_0 2768 330 221	T_2 4309 198** 19	T_0 3608 653** 198
F nonsignificant	F nonsignificant	L. S. D. 140 ; 183	L. S. D. 126 ; 171

Hsinchu	Pingtung	Chiayi
Mean	Mean	Mean
G_0 4125	G_0 3225	G_1 4169
G_2 4060 65	G_1 3136 89	G_0 3989 180
G_1 3708 417** 352**	G_2 3136 89 0	G_2 3941 228 48
L. S. D. 192 ; 290	F nonsignificant	F nonsignificant
L_1 4053	L_0 3206	L_1 4071
L_0 3876 177**	L_1 3126 80	L_0 3995 76
L. S. D. 135 ; 193	F nonsignificant	F nonsignificant
T_2 4126	T_2 3183	T_2 4097
T_1 3933 193	T_1 3178 5	T_1 4018 79
T_0 3835 291** 98	T_0 3136 47 42	T_0 3985 112 33
L. S. D. 199 ; 267	F nonsignificant	F nonsignificant

尿素肥料施肥法試驗成績

（第一報）

李蘭帝　許新民　林金燦　林國謙

1. 本試驗之目的在探求尿素對水稻之最合理之施肥法。試驗包括三因子：①施肥後之灌溉時期，②施肥位置，③追肥方法。試驗在民國四四年，在全省七處舉行。
2. 另行室內實驗包括：①土壤一般分析，②尿素在土壤中分解速度之測定，③尿素施用後揮散氨量之測定等。
3. 全層施肥及施行追肥均可提高稻谷收量，灌溉時期之影響不顯著，尚待將來之研究。
4. 尿素施於土壤後在三至五日之內其大部份可分解，並且氨之揮散量顯然較硫銨爲多。

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